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Original Article

Determination Of Radon Level In Drinking Water In Mehriz Villages And Evaluation The Annual Effectiveabsorbed Dose

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Abstract

Introduction: Radon is one of the most radioactive elements that may be found in soil, air and water naturally. Presence of fault and also granitic rocks near the water sources can cause high radon levels in these water resources. Radon concentration of various drinking water sources And network In Mehriz Villages was measured from Anar-Mehriz fault and granite stone of Shirkooh area.

Material and Methods: This was a cross sectional research that was conducted in fall of 2013 on the sources of drinking water and also drinking water network of Mehriz villages of Yazd province. After sampling and sending samples to the laboratory, radon concentration was measured by RAD7 device.According to the measured radon levels, the annual absorbed dose was also calculated.

Results: Radonconcentrations of samples ranged from 0.187 BqL-1 to 14.8 BqL-1.These results were related to samples No.12 and 9 and also to aqueducts of Tang-e-chenar and Malekabad village respectively.Based on the amount of radon in the sample, the lowest annual effective absorbed dose through drinking water or breathing(In an environment where water was used) was 0.0005msv/y and the maximum amount was 0.04msv/y.

Conclusion: Apart from samples No.9 and 16 that were related to the aqueduct of Malekabad village and a private well in Dare Miankooh village having 48 persons as total population,Radon concentrations of other samples used by people of Mehriz villages as drinking water was low and less than permitted limit set by the Environmental Protection Agency of United States of America.

Keywords: Radon, drinking water, effective dose, Mehriz

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Introduction

Iran has shown constant high seismicity throughout its history as a result of its location in Asia – Himalaya orogenic belt [1]. In most parts of Iran, the seismicity occurring was directly linked to the resurgence of active faults [1]. Some particular symptoms can inform humans to forecast earthquakes. These symptoms include displacement of fault page or bending on the ground surface, increasing tension in the fault zone or ground surface rocks (It requires very sensitive devices), changing magnetic field with earth's gravity, , changing the emission of radon gas in the soil and groundwater and changes in animal behavior, P-wave velocity change provided that care and continuous measurements in seismic areas are considered [2]. Changes in groundwater solution radon concentration are one of earthquake precursors[3]. Various ways are used to measure radon concentration such as measurement of soil depth, measurement of dissolved gas concentrations in groundwater including deep wells, hot Springs or ground surface and near faults. Environmental factors such as pressure, temperature, humidity and soil are possible factors that can affect the measured radon concentration, depending on the method of measurement[4]. Radon is a natural radioactive element with no odor and color. It is the result of uranium, radium and thorium decay, which are naturally found in earth. Radon is the most stable isotope of Uranium -238 (U-238) with half-life about 3.8 days [5]. Radon gas is the heaviest radioactive element shown as Rn-222 and is naturally available in rocks, soil and water. This gas does not have a great affinity for water and soil. It can easily separate from soil and water and join air molecules [6]. Radon concentration will be different due to the wide range of uranium concentrations in soils and rocks [7]. Total Radon emitted from the Earth's landmass is equal to 8.88 ×1019Bq in a year [8].Radon is a radioactive gas that exists in drinking water and breathing air. So it is a main cause of lung cancer in some countries [9].

International Commission on Radiological Protection (ICRP)declares that the radionuclide content in water is absorbed much easier than food radionuclide.Rn-222 is dissolved in groundwater and its concentration changes from a few Bq / Lit up to thousands Bq / Lit.The highest concentration of radon is reported from existing water in bedrocks [10].The amount of groundwater radon is dependent on the concentration of radium in the aquifer layer [11]. The amount ofRn-222 in surface waters is generally too low [10]. Radon -222, the inert gas has low solubility in body fluids [12]. For this reason it distributes uniformly in the body [12]. Radon will convert to a series of short-lived elements called radon daughters (Po-218 and Po-214) byalpha particle radiation [12]. Plutonium 218 (half-life of three minutes) and plutonium 214 (half-life two-tenths of a second) are solid particles that considered as effective biological risk. These radioactive products are produced in lungs due to inhalation and decay of radon. Then a short time later they decay and cause DNA molecules damage and production of Free radicals by irradiation high-energy alpha particles. Due to this fact radon is presented as lung cancer factors[12]. In addition to the respiratory system, the alpha particle induced from decay of radon leads to gastrointestinal tract damage. Gastric cancer is one of them. Radon is divalent and similar to calcium so an important part of it is absorbed into the blood stream,concentrated in bones and increases internal exposure rate [13]. A study in 2011 by Binesh and colleagues was performed on seasonal changes in radon concentration in drinking water of Shandiz in Mashhad [6].Another study in 2011 by Negarestani and colleagues was done on effective dose caused by radon of hot springs of Joshan in Kerman province [12]. Another study in 2012 by Tabassum Nasir and colleagues was conducted on effective dose caused by radon in drinking water and home of Karachi [10]. Measuring radon in drinking water of villages of Mehriz city (periphery of Shirkooh Mountain) was considered due to presence ofMehriz-Anar fault in the studied area, Bahadoran earthquake zone and also the presence of part of Shirkooh area with granite rocks were two reasons for the emergence of radon in water. Several villages are located in study area where country place is and also there are plenty of houses and villas. These buildings have private wells and use taken water immediately before release of radon gas. For this reason radon gas separation time from the water is short and evaluation of radon concentration in this region is necessary. In this case, by observing wells containing high radon concentrations water, permanent monitoring and earthquake forecasting can be made. Also if radon concentration rate is higher than recommended levels, necessary measures should be initiated to prevent health damages from water consumption, drinking, washing and bathing.

Materials and Methods

Sectional study was conducted at the Environmental Health Engineering Research Center of Kerman University of Medical Sciences in autumn 2013 about water resources and some of drinking water network of Mehriz villages in Yazd province. Firstly, fault location, villages, fountains, aqueducts were identified using geological and topographical maps and satellite photographs of the study area. Arc Gis software was used and sampling locations were identified on the map.

In the present research 38 samples were collected from 29 villages. Sampling was done after opening the faucet or switching the well pump and after minutes with minimal contact with air. Date and time of sampling were recorded and samples were stored in a cooling unit. Water temperature, electrical conductivity and PH of each sample were measured at each sampling site.

Sampling and testing of this part of the research were based on methods described in “Standard test methods for the examination of water and wastewater” [14].

In each round and after some sampling, water samples under standard conditions were transferred to the laboratory to measure radon concentration immediately. The measurements were performed by RAD7 H2O that is the electronic radon detector manufactured by DURRIDGE COMPANY Inc.

To ensure test accuracy based on set standards the Environmental Protection Agency of United States of America (EPA), two samples of drinking water were taken simultaneously from each site. RAD7 devices then measured the amount of radon concentration in water samples. Figure 1 shows the location of sampled water and central village name of Mehriz city (some sampling locations are shown superposed on the map due to their proximity)

Figure 1. location of sampled water and central village name of Mehriz city [15].

The average radon concentration in the water which was provided by the device is in terms of Bq/m3but it was converted to Bq/Lit.A=A0e (-0.693/T) t formula was used to apply the effect of duration of sampling and testing on half-life of radon. In this formula, A is the average radon concentration in water samples (Bq/Lit) that is measured by RAD7 devices, T is half-life of radon (3.8 days), t is duration of sampling until testing and A0is actual radon concentration of water samples [16].

Recommended parameters by UNSCER (United Nations Scientific Committee on the Atomic Radiation) in 2000 were used to calculate the annual effective absorption dose caused by inhalation and ingestion of radon. The annual effective absorbed dose which caused by drinking water containing radon 1Bq/Lit was considered equivalent to 0.18 µsv / y. The annual effective absorbed dose due to inhalation corresponding to the concentration of 1Bq/Lit in tap water (Always, there is radon gas caused by evaporation and release of it in air surrounded water containing radon) was considered equivalent to 2.5 µsv / y. Thus, total annual effective absorbed dose rate from inhalation and ingestion of radon in 1 Bq/Lit of water is equal to 2.68 µsv / y which annual effective absorbed dose was calculated by multiplying it to the radon concentration in each sample [17].

Results

The electrical conductivity of the water samplesrangedfrom386 (µs/cm)to6100(µs/cm). pH of samples was between 6 to 8.7.Water temperatures were between 12°Cto22.6°C.Specifications of water sampling points included address and geographical coordinates, type of sample resources (well, water tap, aqueduct etc.), radon concentration of samples and annual absorbed dose for a middle aged person are given in Table 1.

Table 1. Specification of water sampling points including address and geographical coordinates, type of sample resources (well, water tap, canals and...), consumer population of sampled water, radon concentration of samples and annual absorbed dose for a middle aged person.

SampleNo	Source	Location(Villages,…)	Lat(N)	Long(E)	Population (body)	RadonConcentration(Bq. L^{-1})	Annualeffective dose(µsv/y)
1	A	Mazrey no	31˙ 24.405´	54˙ 19.079´	174	1.309	0.003
2	P H W	Tangechenar	31˙ 23.875´	54 20.707´	5	4.448	0.012
3	A D W	Karimabad (Bahadoran)	31˙ 18.378´	54˙ 57.226´	12	7.047	0.019
4	A D W	Mohammadabad (Bahadoran)	31˙ 21.741´	54˙ 53.690´	35	4.240	0.011
5	A D W	Mahdiabad (Bahadoran)	31˙ 27.495´	54˙ 53.867´	40	0.632	0.0017
6	A D W	Aliabad	31˙ 15.839´	54˙ 15.765´	32	0.231	0.006
7	A D W	Aliabad	31˙ 15.832´	54˙ 15.764´	32	2.761	0.007
8	P H W	Paizan	31˙ 26.714´	54˙ 19.009´	*	6.966	0.02
9	A	Malekabad	31˙ 26.086´	54˙ 19.528´	43	14.800	0.04
10	A D W	Sarv(Ernan)	31˙ 19.224´	54˙ 10.595´	42	4.020	0.01
11	T	Ernan	31˙ 19.224´	54˙ 09.431´	3452	6.537	0.0176
12	A	Tangechenar	31˙ 23.753´	54˙ 20.587´	802	0.864	0.002
13	T	Baghdeyhook	31˙ 33.698´	54˙ 27.987´	500	3.802	0.01
14	A	Baghdeyhook	31˙ 33.742´	54˙ 27.982´	141	0.949	0.0025
15	P H W	Darehmiankoo	31˙ 35.547´	54˙ 15.809´	5	1.484	0.004
16	P H W	Darehmiankoo	31˙ 35.354´	54˙ 15.862´	5	12.200	0.03
17	P H W	Afshani	31˙ 35.354´	54˙ 15.573´	5	0.701	0.002
18	P H W	Manshad	31˙32.123´	54˙ 13.442´	5	2.322	0.0062
19	P H W	Manshad	31˙ 31.190´	54˙ 13.190´	430	3.293	0.0088
20	P H W	Banadakesadat	31˙ 4.380´	54˙ 12.140´	5	5.164	0.014
21	P H W	Banadakesadat	31˙ 34.658´	54˙ 11.964´	5	4.413	0.011
22	P N W	Madvar	31˙ 31.322´	54˙ 24.180´	986	4.855	0.013
23	P N W	Baghdeyhook	31˙ 33.771´	54˙ 28.22´	500	2.700	0.007
24	P N W	Saryazd	31˙ 36.375´	54˙ 28.907´	421	2.520	0.0067
25	P N W	Mehriz	31˙ 35.541´	54˙ 27.163´	27112	1.254	0.003
26	P N W	Mehriz	31˙ 35.642´	54˙ 26.979´	27112	5.150	0.0138
27	P N W	Mehriz	31˙ 35.668´	54˙ 26.492´	27112	4.766	0.0127
28	P N	Sarbagh (Manshad)	31˙	54˙	27112	5.984	0.016

	W		31.615´	12.865´			
29	P N W	Banadaksadat (olia)	31˙ 33.982´	54˙ 11.634´	402	8.248	0.022
30	P N W	Banadaksadat (Sofla)	31˙ 34.930´	54˙ 13.174´	402	7.185	0.019
31	P N W	Seyydabad	31˙ 37.093´	54˙ 12.227´	234	4.295	0.011
32	P N W	Henzaolia	31˙ 37.092´	54˙ 12.228´	1500	2.268	0.006
33	P N W	Tangechenar	31˙ 19.906´	54˙ 15.562´	1400	10.092	0.027
34	P N W	Ahmadabad	31˙ 17.839´	54˙ 13.092´	32	2.384	0.06
35	P N W	Abdollaabad	31˙ 17.641´	54˙ 19.165´	99	4.284	0.011
36	P N W	Eslamabad	31˙ 17.423´	54˙ 16.427´	42	2.448	0.006
37	P N W	Aliabad	31˙ 17.253´	54˙ 16.144´	332	1.560	0.004
38	T	Tangechenar	31˙ 23.889´	54˙ 20.160´	1400	3.060	0.008

Symbols: A: Aqueduct, P H W:Private home wells, A D W: Agriculture and drinking water wells,T: Tap, P N W: public network wells

The maximum measured radon gas of sources was 14.8 Becquerel per liter (sample No. 9) related to outlet of Deh aqueduct located in Malekabad village and the minimum amount of radon in water was 0.187 Becquerel per liter (samples No. 12) which was related to the outlet of Tangh-e-chenar subterranean. Sample No.9 had the maximum amount of annual absorbed dose (0.04mSv per year) and sample No.12 had the minimum amount of annual absorbed dose (0.0005 mSv per year).

Discussion

Permissible limit of dissolved radon of water recommended by the Environmental Protection Agency of America (EPA) is 11 Bq/L [11].The amount of radon gas of samples No. 9 and 16 were 14.18 and 12.2(Bq/L) respectively. Sample No. 9 belonged to outlet of Deh aqueduct in Malek Abad village. With respect to presence aspects in sampling time and questioning of village residents, the water of this subterranean was being used for drinking due to its fresh water and good flavor. Sample No. 16 was taken from a private well of a resident of DarehMiankooh Village. This water was also used for drinking. According to land characteristics, the water of these aqueducts passes through different veins of granitic rocks that could be the reason for high radon concentration in water. The aqueduct radon would usually sip out because some of subterranean wells were not covered and also the outlet of aqueduct was a half-filled water way. But in Malek Abad village, aqueduct wells have been covered and the water comes out in completely filled tube at outlet of the aqueduct. Probably these were the two reasons leading to higher radon levels in water of aqueduct than other aqueducts in study area. Zareaee 2009 investigated the natural radionuclides of granite in Shirkooh mountain area. It was determined that the maximum value of the specific activity of 238U (57.2Bq/Kg) and maximum value of the specific activity of232Th (85Bq/Kg) (which are the last element in the uranium decay chain and before radon)were related to rocks of Dare Miankooh region [18].Sample No. 16 was taken from the DarehMiankooh village. Necessary arrangements should be considered by relevant authorities due to using water for drinking immediately after the extraction in these two places. In none of samples related to supplier wells of the general network of rural water (owned water and Sewage Company) radon concentration levels was more than permitted limit. However sampling was also carried out from the public network water. In case of high levels of radon in samples taken from wells, Radon gas levels related to the same well needed to be investigated. For example, sample No. 33, related to water wells of general network of drinking located in Tangh-e-chenar village with concentration of 10.092 (Bq/L) was close to the maximum allowable limit. However, due to the long distance of the village from wells and magnitude storage tank before entering to the public water network and also sampling time (Relatively cool season, less consumption of water, more water retention in reservoir, transmission lines and rural distribution networks) the amount of radon gas on public networks decreased to 3.060 Becquerel per liter (sample No.38) due to release this gas from water and also decays in interval time from extraction to consumption water.

A study in 2011 by Binesh and colleagues was performed on seasonal changes in radon concentration in drinking water of Shandiz in Mashhad. This study showed that Radon concentration was different in various seasons and with the exception of two samples out of 40 samples that were taken from 10 fixed points during 4 seasons, in other cases, the measured concentrations were higher in autumn [6]. In this study radon measurement in water of Mehriz city has been done in 2013 fall. So, probably the provided radon concentration values were the highest possible.

Another study by Purhabibi and colleagues was performed on the presence of radon in rivers and water faucet of public network in Ramsar in 2011. The study found that the average radon of streams was 2.689 Becquerel per liter and the average amount of radon in drinking water was 3.404Becquerel per liter. Ramsar area has high exposure and since the river water is in contact with air, radon will be released. Drinking water sampled from tap water was found to have low level of radon due to the long extraction time [13].This result was consistent with results of this research.

In 2005, Alirezazadeh measured radon levels in groundwater and surface water sources in Tehran. An average radon level of surface water was 2.5 Becquerel per liter and the average radon levels of groundwater was 46.4 Becquerel per liter. Remarkably, after extraction and mixed with surface water and with regard to long extraction time the radon rates were significantly decreased .This is consistent with results of this research [19].

In the study by Tabassum Nasir et al in 2012 about the effective dose caused by radon in drinking water in Karachi, radon concentrations in all samples were less than recommended amount by US-EPA (11Bq/Lit)[10], a result consistent with the bulk of results of this research.

A study was conducted in 2014 in Iran by Malakootian et al and colleagues on 56 samples of drinking water in villages surrounding Rafsanjan fault in order to evaluate radon concentration and calculate the annual effective dose of consumption water. Radon concentration in 8 samples was higher than the limit set by the EPA. High concentration of radon gas is due to presence of Rafsanjan fault and fine faults in the study area[20].

In this study, the radon concentration was measured. According to World Health Organization guidelines (on drinking water quality), the annual effective absorbed dose values of all radionuclides which enter the body through drinking water should not be more than 0.1mSv in a year [21].

Conclusion

Apart from samples No.9 and 16 that were related to the aqueduct of Malekabad village and a private well in Dare Miankooh villagehaving48 persons as total population, Radon concentrations of other samples used by people of villages (located in Mehriz city) as drinking water was low and less than permitted limit set by the Environmental Protection Agency of United States of America. In order to avoid using these two water sources, notices should be done. Interval time of with draw water from these two sources and consuming should increase enough in order to reduce radon level in these two water sources by releasing radon gas from water.

Considering the amount of radon in samples, the annual absorbed dose of radon through drinking or breathing air in an environment where the water was consumed was calculated. Its lowest value was o.0005 msv/y related to sample No. 12 and the maximum amount was 0.04 msv / y related to sample number 9.Malek Abad village population consisted of 43 people exposed to these values. However, the maximum amount was less than permitted limit by WHO.

It is recommended that in the course of further research, other radioactive substances in drinking water be tested in order to achieve total absorbed dose rate. The other suggestion is the evaluation of radon in water of Taftcity which is adjacent to this area due to the long Dehshir - Baft fault and Shirkoohmountain (with granite stones).

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